Claims

1. A laminar flow control apparatus comprising:

an outer skin having a plurality of perforations communicating therethrough, and having an outer surface adapted to be exposed to an airflow including a boundary layer airstream flowing along said outer surface; and

a suction system communicating with said perforations on a side of said outer skin opposite said outer surface and adapted to suck air from the boundary layer airstream through said perforations;

wherein flow disturbances are created in the boundary layer airstream due to the sucking of the air through said perforations;

characterized in that said perforations are spatially distributed in a spatial pattern of said perforations such that the flow disturbances undergo mutual destructive interference at least at one or more selected wavelengths.

2. The laminar flow control apparatus according to claim 1, characterized in that said spatial pattern of said perforations is arranged so that the sucking of the air through said perforations generates a minimum excitation of flow instabilities in the boundary layer airstream.

3. The laminar flow control apparatus according to claim 1, characterized in that said spatial pattern of said perforations has a spatial spectrum essentially absent of energy at said one or more selected wavelengths.

4. The laminar flow control apparatus according to claim 1, characterized in that said one or more selected wavelengths correspond to flow wavelengths of predetermined flow instabilities appearing in the boundary layer airstream.

5. The laminar flow control apparatus according to claim 1, characterized in that said one or more selected wavelengths correspond to flow wavelengths of predetermined unstable flow modes appearing in the boundary layer airstream at a particular chordwise location at which at least a selected portion of said spatial pattern of perforations is located on said outer skin.

6. The laminar flow control apparatus according to claim 1, characterized in that said spatial pattern comprises at least one elongated longitudinally extending bundle of at least one longitudinally extending row of said perforations, which are respective micro-slots each having a length in a range of 100 to 3000 μm and a width in a range of 50 to 250 μm.

7. The laminar flow control apparatus according to claim 1, characterized in that said spatial pattern comprises a plurality of elongated longitudinally extending perforation bundles which are arranged parallel to each other and spaced apart from one another with respective major unperforated skin areas therebetween, and which each include a plurality of longitudinally extending rows of said perforations, wherein said rows are arranged parallel to each other in row groups of adjacent ones of said rows respectively having said perforations staggered from one another, and with minor unperforated skin areas between adjacent ones of said row groups within each one of said bundles.

8. The laminar flow control apparatus according to claim 7, characterized in that said row groups in a respective one of said bundles respectively include different numbers of said rows of said perforations.

9. The laminar flow control apparatus according to claim 1, characterized in that said spatial pattern comprises plural

elongated longitudinally extending perforation bundles which each include plural longitudinal rows of said perforations, wherein said bundles are arranged parallel to each other and spaced apart from one another with unperforated skin areas therebetween, and wherein said rows of said perforations are arranged to generate said destructive interference relative to each other and said perforation bundles are arranged to generate said destructive interference relative to each other.

10. A laminar-flow control surface exposed to a boundary-layer air stream, said control surface comprising:

an outer skin with a plurality of primary perforations through said skin;

a suction system coupled to said outer skin to draw air from said boundary-layer air stream through said primary perforations;

wherein said primary perforations are spatially distributed with respect to each other to generate a minimum excitation of flow instabilities in said boundary-layer air stream.

11. A laminar-flow control surface exposed to a boundary-layer air stream, said control surface comprising:

an outer skin with a plurality of primary perforations through said skin;

a suction system coupled to said outer skin to draw air from said boundary-layer air stream through said primary perforations;

said primary perforations having a spatial spectrum essentially absent of energy at predetermined wavelengths such that disturbances in said boundary-layer air stream created by said drawing of said air through said primary perforations at least partially cancel each other through destructive interference at said predetermined wavelengths.

12. In an aircraft having an airfoil that includes a leading edge and an outer skin with an outer surface adapted to have a boundary layer airstream flow therealong and that has perforations communicating through said outer skin to said outer surface,

an improvement characterized in that:

said perforations are spatially arranged in elongated bundles of said perforations,

said bundles extend longitudinally essentially parallel to said leading edge and to each other, and said bundles are laterally spaced apart from one another by respective major unperforated skin areas therebetween, and

each one of said bundles includes plural longitudinally extending rows of said perforations.

13. The improvement in the aircraft according to claim 12, characterized in that each one of said perforations is an elongated slot having a length in a range of 100 to 3000 μm and a width in a range of 50 to 250 μm.

14. The improvement in the aircraft according to claim 13, characterized in that said length is not greater than 500 μm.

15. The improvement in the aircraft according to claim 13, characterized in that said length is not greater than 300 μm.

16. The improvement in the aircraft according to claim 12, characterized in that each one of said perforations of a respective one of said bundles is an elongated slot having a long axis oriented parallel to a longitudinal extension direction of said respective bundle.

17. The improvement in the aircraft according to claim 12, characterized in that each one of said perforations of a respective one of said bundles is an elongated slot having

a long axis oriented perpendicular to a longitudinal extension direction of said respective bundle.

18. The improvement in the aircraft according to claim 12, characterized in that each one of said perforations of a respective one of said bundles is an elongated slot having a long axis oriented at an oblique angle to a longitudinal extension direction of said respective bundle.

19. The improvement in the aircraft according to claim 12, characterized in that said perforations are elongated slots having long axes thereof oriented parallel to each other within each respective one of said bundles, and said slots of a first one of said bundles are oriented with said long axes thereof in a different direction in comparison to said long axes of said slots of a second one of said bundles.

20. The improvement in the aircraft according to claim 19, characterized in that said slots of each respective one of said bundles are oriented with said long axes thereof essentially perpendicular to a local flow direction of the boundary layer airstream flowing over said respective bundle.

21. The improvement in the aircraft according to claim 19, characterized in that said slots of each respective one of said bundles are oriented with said long axes thereof essentially parallel to a local flow direction of the boundary layer airstream flowing over said respective bundle.

22. The improvement in the aircraft according to claim 12, characterized in that said rows of said perforations in a respective one of said bundles are arranged in plural parallel row groups of adjacent ones of said rows respectively having said perforations staggered from one another and with minor unperforated skin areas between

adjacent ones of said row groups within said respective bundle.

23. The improvement in the aircraft according to claim 22, characterized in that a first one of said row groups within said respective bundle has a different length, width, orientation, spacing, periodicity, staggering, number, or pattern of said perforations in comparison to a second one of said row groups within said respective bundle.

24. The improvement in the aircraft according to claim 23, characterized in that said perforations are holes with a circular cross-section.

25. The improvement in the aircraft according to claim 12, wherein the aircraft further includes a suction system that communicates with said perforations and that is adapted to suck air from the boundary layer airstream through said perforations, characterized in that flow disturbances are created in the boundary layer airstream due to the sucking of the air through said perforations, and said perforations are spatially distributed in a spatial pattern in at least one of said bundles such that the flow disturbances undergo destructive interference with each other at least at one or more selected wavelengths.

26. The improvement in the aircraft according to claim 25, characterized in that said spatial pattern of said perforations has a spatial spectrum essentially absent of energy at said one or more selected wavelengths.

27. The improvement in the aircraft according to claim 25, characterized in that said one or more selected wavelengths correspond to flow wavelengths of predetermined flow instabilities appearing in the boundary layer airstream.

28. The improvement in the aircraft according to claim 12, further comprising structurally supporting ribs extending along and joined to said outer skin on a side thereof opposite said outer surface at said major unperforated skin areas.

29. The improvement in the aircraft according to claim 28, characterized in that said outer skin and said ribs are integral with one another and together form an integral unitary component.

30. The improvement in the aircraft according to claim 28, further comprising an inner plate joined to said ribs opposite and spaced from said outer skin, thereby forming air channels respectively bounded between said outer skin, said inner plate and respective adjacent ones of said ribs, wherein said inner plate has holes communicating therethrough into said air channels, and said holes provide different respective total porosities of said holes communicating into different ones of said air channels.

31. An airfoil having an outer surface sustaining a boundary-layer air stream, said airfoil having a forward leading edge and having at least part of said outer surface comprising a laminar-flow control surface exposed to said boundary-layer air stream, said control surface comprising:

an outer skin with a plurality of primary perforations through said outer skin;

a suction system coupled to said outer skin to draw air from said boundary-layer air stream through said primary perforations, thereby causing disturbances in said boundary-layer air stream;

said primary perforations forming a plurality of spaced apart, longitudinal perforated areas aligned essentially parallel to said leading-edge of said airfoil and separated from one another by non-perforated surface areas, at least one of said longitudinal perforated areas

having primary perforations distributed to produce destructive interference between said disturbances, said destructive interference occurring downstream of said at least one of said longitudinal perforated areas at predetermined spatial wavelengths.